Epiduroscopy for Patients With Lumbosacral Radicular Pain

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Abstract: Lumbosacral radicular pain is a pain in the distribution area of one of the nerves of the lumbosacral plexus, with or without sensory and/or motor impairment. A major source of lumbosacral radicular pain is failed back surgery, which is defined as persistent or recurrent pain, mainly in the region of the lower back and legs even after technically, anatomically successful spine surgeries. If lumbosacral radicular neuropathic pain fails to respond to conservative or interventional treatments, epiduroscopy can be performed as part of a multidisciplinary approach. Epiduroscopy aids in identifying painful structures in the epidural space, establishing a diagnosis and administering therapy. The novelty consists in the use of an epiduroscope to deliver therapies such as adhesiolysis and targeted administration of epidural medications. Clinical trials report favorable treatment outcomes in 30% to 50% of patients. Complications are rare and related to the rate or volume of epidural fluid infusion or inadvertent dural puncture. In patients with lumbosacral radicular pain, especially after back surgery, epiduroscopy with adhesiolysis may be considered (evidence rating 2 B†).

Key Words: epiduroscopy, adhesiolysis, evidence-based medicine, low back pain, systematic review

INTRODUCTION AND RATIONALE FOR THE USE OF EPIDUROSCOPY

This review on epiduroscopy is part of the series “Evidence-based Interventional Pain Medicine According to Clinical Diagnoses.” Recommendations formulated in this article are based on “Grading strength of recommendations and quality of evidence in clinical guidelines” described by Guyatt et al., and adapted by van Kleef et al. in the editorial accompanying the first article of this series (Table 1). The latest literature update was performed in May 2012.

Lumbosacral radicular pain defined as pain in the distribution area of one of the nerves of the lumbosacral plexus, with or without sensory and/or motor impairment. In randomized trials, less than 50% of patients achieve adequate pain relief from drugs and side effects often dissuade their use. Moreover, medications
Table 1. Summary of Evidence Scores and Implications for Recommendation

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Implication</th>
</tr>
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<tbody>
<tr>
<td>1 A</td>
<td>Effectiveness demonstrated in various RCTs of good quality. The benefits clearly outweigh risk and burdens</td>
<td>Positive recommendation</td>
</tr>
<tr>
<td>1 B</td>
<td>One RCT or more RCTs with methodological weaknesses, demonstrate effectiveness.</td>
<td></td>
</tr>
<tr>
<td>2 B</td>
<td>One or more RCTs with methodological weaknesses, demonstrate effectiveness. Benefits closely balanced with risk and burdens</td>
<td></td>
</tr>
<tr>
<td>2 B</td>
<td>Multiple RCTs, with methodological weaknesses, yield contradictory results better or worse than the control treatment. Benefits closely balanced with risk and burdens, or uncertainty in the estimates of benefits, risk and burdens.</td>
<td>Considered, preferably study-related</td>
</tr>
<tr>
<td>2 C</td>
<td>Effectiveness only demonstrated in observational studies. Given that there is no conclusive evidence of the effect, benefits closely balanced with risk and burdens</td>
<td>Only study-related</td>
</tr>
<tr>
<td>0</td>
<td>There is no literature or there are case reports available, but these are insufficient to prove effectiveness and/or safety. These treatments should only be applied in relation to studies.</td>
<td></td>
</tr>
<tr>
<td>2 C</td>
<td>Observational studies indicate no or too short-lived effectiveness. Given that there is no positive clinical effect, risk and burdens outweigh the benefit</td>
<td>Negative recommendation</td>
</tr>
<tr>
<td>2 B</td>
<td>One or more RCTs with methodological weaknesses, or large observational studies that do not indicate any superiority to the control treatment. Given that there is no positive clinical effect, risk and burdens outweigh the benefit</td>
<td></td>
</tr>
<tr>
<td>2 A</td>
<td>RCT of a good quality, which does not exhibit any clinical effect. Given that there is no positive clinical effect, risk and burdens outweigh the benefit</td>
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</table>

RCT, randomized controlled trial.

effective in diabetic polyneuropathy and postherpetic neuralgia failed to demonstrate superiority over placebo in radicular neuropathic pain. Failed back surgery syndrome (FBSS) is a major source of lumbosacral radicular pain defined as persistent or recurrent pain, mainly in the region of the lower back and legs even after technically, anatomically successful spine surgeries. Possible causes of FBSS are postoperative inflammation or epidural fibrosis.

If lumbosacral radicular neuropathic pain fails to respond to conservative treatment such as physical therapy and medication or interventional treatments such as transforaminal epidural corticosteroid injections, Racz procedure, or (pulsed) radiofrequency treatment adjacent to the dorsal root ganglion, epiduroscopy can be performed as part of a multidisciplinary approach before spinal cord stimulation is considered. Epiduroscopy offers several advantages: (1) confirmation of the diagnosis of radicular pain; (2) mechanical removal of adhesions; and (3) targeted administration of drugs.

As early as 1931, Burman used arthroscopic equipment to examine the anatomy of the vertebral column removed from cadavers. A few years later, the American neurosurgeon, Pool, reported on over 400 spinal endoscopies. Later, Ooi also applied the technique in patients. These early studies specifically inspected the intrathecal space. Afterward, the technique was primarily used for examining the epidural space. Shimoji et al. added 2 important features to the technique, namely performing epiduroscopy under conscious sedation and identifying the affected nerve root by touching it and reproducing the patient’s pain. In 1994, Saberski and Kitahata described the caudal approach, which greatly reduced the risk of dural puncture. They also were the first to describe the use of a flexible, steerable epiduroscope, and irrigation of the epidural space with saline to aid visualization.

**DIAGNOSIS**

Epiduroscopy is first and foremost a diagnostic procedure that can assess the cause of radicular pain. Visualization of the epidural space allows for evaluation of nerve roots and identification of adhesions, inflammation, and other abnormalities. Epiduroscopy is more sensitive than MRI in detecting epidural fibrosis. In a recent study, in patients with failed back surgery syndrome, MRI showed epidural fibrosis in 16.1% whereas, with epiduroscopy, this was the case in 91% of the patients. (See Table 2).

The added value of epiduroscopy for diagnosis is due to the functional nature of the procedure. Touching epidural structures with the tip of the scope enables assessment of the precise source of the radicular pain by reproducing the patient’s pain. In this respect, epidu-
Epiduroscopy is also superior to MRI or clinical examination.20

“Healthy” nerve roots are visualized through the dura and appear as white or pale pink structures (Figure 1) with a blood vessel longitudinally running along the surface. A healthy nerve root may show pulsations, which are conducted from the dural sac. The absence of pulsations may indicate the presence of edema or excessive adhesions. Inflamed nerves are red and swollen (“angry red swollen nerve”), do not usually pulsate, and are painful when touched (Figure 2).

Table 2. Comparison of Epiduroscopy and MRI for the Diagnosis and Treatment of Chronic Radicular Pain

<table>
<thead>
<tr>
<th></th>
<th>Epiduroscopy</th>
<th>MRI Scan</th>
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<tbody>
<tr>
<td>Nerve root anatomy</td>
<td>+ (only details visible)</td>
<td>++</td>
</tr>
<tr>
<td>Nerve root perfusion</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>Nerve root inflammation</td>
<td>++</td>
<td>+/-</td>
</tr>
<tr>
<td>Excitability of nerve root</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>Locating the painful nerve root</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>Identifying scar tissue</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Identifying herniated disk</td>
<td>– (structure in anterior epidural space)</td>
<td>++</td>
</tr>
<tr>
<td>Evaluating diameter of spinal canal</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td>Excluding serious pathology</td>
<td>+/- (biopsy possible)</td>
<td>++</td>
</tr>
<tr>
<td>Therapeutic options</td>
<td>++</td>
<td>–</td>
</tr>
</tbody>
</table>

++ = highly valuable; + = valuable; +/- = possibly useful—no added value.

The dura is a visible blue–gray structure covered by a “network” of small blood vessels and may pulsate.

Adhesions are white or gray, can completely cover the nerve, and are painful when touched near the affected nerve. Adhesions that develop following back surgery or because of inflammation may contain blood vessels when viewed before the scarring has fully matured. Touching adhesions can discriminate soft adhesions, which are easy to remove, from rigid adhesions, which are difficult to remove. This discrimination is important for determining the efficacy of adhesiolysis and therefore the outcome of the procedure.

**MECHANISMS OF ACTION**

**Adhesiolysis**

Adhesions attached to affected nerve roots or the dura can be removed by mechanically scraping off the fibrosis with the tip of a video-guided catheter or epiduroscope and/or by the hydrostatic pressure produced by saline flushes. Recent publications describe the use of Fogarty catheters and resablation to remove adhesions attached to the dura. The aim is to liberate the nerve or dura, in order to increase the mobility of the nerve, and hence restore the supply of nutrients (ie, nerve growth factor-NGF) and blood flow to the nerve.21,22 Moreover, flushing of the epidural space with saline dilutes or washes out inflammatory mediators that have leaked.

Figure 1. Visualization of a nerve root in the subarachnoid space; the nerves have a normal white aspect with a blood vessel running longitudinally.

Figure 2. Visualization of an inflamed epidural space; note the peridural fatty tissue in the right lower quadrant; visualization of the dura with a roadmap of vessels running around it and visualization of an inflamed nerve in the middle lower quadrant.
Adhesions around nerves considered to be asymptomatic are left untouched. This procedure must be carried out carefully, in constant communication with the lightly sedated, cooperative patient. If the patient is in much pain or complains of nontransient paresthesias, severe pain, or neck pain, the adhesiolysis must be discontinued immediately.

**Targeted Therapy**

In FBSS patients, epidurally applied corticosteroids attain the intended level in 26% of cases. A major advantage of epiduroscopy is that it allows for accurate placement of drug in the epidural space.

Table 3 summarizes the proposed mechanisms for the therapeutic efficacy of epiduroscopy.

**INDICATION(S) AND PATIENT SELECTION**

Epiduroscopy can be considered in patients with chronic lumbosacral radicular pain, including FBSS patients, refractory to conservative therapy (physical therapy, medication) or minimally invasive therapeutic techniques (epidural corticosteroid injections, RACZ procedure, (pulsed) radiofrequency treatment adjacent to the dorsal root ganglion).

Flushing the epidural space and adhesiolysis are essential components of the procedure, which make this procedure particularly suited for the management of radicular pain due to fibroses and inflammation, which is often the case in patients with FBSS.

Patient selection depends on the duration of symptoms, the extent of adhesions, and the patient’s history as illustrated in Figure 3.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>References</th>
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<tbody>
<tr>
<td>Dilution or “washing out” of inflammatory mediators that have leaked from</td>
<td>18,23–29</td>
</tr>
<tr>
<td>the damaged intervertebral disk and the facet joints</td>
<td></td>
</tr>
<tr>
<td>Accuracy of placement of a cocktail of corticosteroids and analgesics</td>
<td>31,32</td>
</tr>
<tr>
<td>near the affected nerve</td>
<td></td>
</tr>
<tr>
<td>Adhesiolysis increases the mobility of the nerve, and hence restores the</td>
<td>21,22</td>
</tr>
<tr>
<td>supplies of nutrients (NGF) and blood to the nerve</td>
<td></td>
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<tr>
<td>Partial denervation of nerve root and dura mater</td>
<td>41,43</td>
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**ANATOMY OF THE EPIDURAL SPACE**

Epidural space means the space surrounding the dura mater. It is sometimes also referred to as “extradural space” or “peridural space,” while others use the term for the space surrounding the dural cuffs and nerve roots (ie, the space surrounding the dorsal root ganglion, DRG). See Figures 4 and 5.

The epidural space is bounded anteriorly by the posterior longitudinal ligament (PLL), the vertebral bodies, and the intervertebral disks, laterally by the intervertebral foramina and the pedicles of the vertebral arches, posteriorly by, alternately, the vertebral arches and the ligamenta flava, and at the level of the sacrum by the fused vertebral arches. As the dural sac ends at the level of the S2 vertebral body, the only tissue caudal to it is epidural fatty tissue with the filum terminale externum and the proximal parts of the nerve roots S2-Cocc1 (Figure 6).

The sacrococcygeal membrane forms the caudal boundary of the sacral epidural space. This membrane seals the sacral hiatus, but it is lacking in about 10% of cases and constitutes the conventional caudal access to the lumbosacral epidural space for epiduroscopy and caudal blocks. Its average anteroposterior diameter is about 4–5 mm, which is enough to allow the epiduroscope (with an external diameter of about 3 mm) to pass through it. However, anteroposterior diameters as small as 1 mm have been reported. This precludes epiduroscopy through the hiatus, and the procedure will then have to be discontinued.

**Tissue Composition**

The epidural tissue comprises loose areolar connective tissue and varying amounts of fatty tissue, which acts as a lubricant for the movements of the nerve roots in the spinal canal. Attention has recently been called to the presence of a peridural membrane. The literature frequently reported the presence of ventral or dorsal septa in the epidural space. The ventral septa connect to the PLL. With dorsal septa, it remains unclear whether they separate the dorsal epidural space into compartments or should be regarded as locally condensed areas in the connective tissue. The consistency of the epidural space contents depends on the patient’s medical history. In some cases, postoperative connective tissue fills up the entire epidural space and it becomes impossible to reach the space cranial to this tissue. Surgeons reported calcified connective tissue plates during repeat operations to
the spine after herniated disk surgery, a finding sometimes encountered during epiduroscopy.

The fatty tissue is mainly located in the anterolateral and dorsomedial parts of the epidural space. Laterally, the lumbosacral epidural space communicates with the fatty tissue adjoining the spinal column, via the intervertebral foramina. Some studies have reported that the epidural space is laterally bounded by the so-called anterior dural ligaments or Hofmann’s ligaments. Finally, intraforaminal ligaments have often been described in the intervertebral foramina, which are thought to serve mostly as fibrous conduits for the emerging nerves.

**Blood Vessels**

The epidural space contains arteries and veins supplying the spinal column. The arteries branch off from the segmental arteries. The veins interconnect, thus forming a venous plexus. This so-called Batson plexus comprises an anterior and a posterior venous part, which are interconnected (the internal vertebral venous plexus) and drain venous blood from the vertebral column, especially from the vertebral bodies. The anterior internal venous plexus is situated between the PLL and the corpora, while the posterior internal venous plexus lies in the posterior epidural space. In the lumbosacral part of the vertebral column, the ventral venous plexus is generally larger than the dorsal plexus, whereas the size of the dorsal plexus increases going from the high lumbar to the low thoracic vertebrae.

These venous plexuses are valveless. The plexuses communicate caudally with the pelvic veins, cranially
with the venous sinuses in the cranium and laterally, via the intervertebral foramina, with the segmental veins (lumbar veins and intercostal veins).

Nerves
All nerves supplying the epidural space branch from the sinuvertebral nerves (Luschka). They branch off the rami communicantes of the spinal nerves return to the epidural space via the intervertebral foramina located ventral to the nerve roots. There they form extensive networks, which provide sensory innervation to the internal parts of the spinal column: the PLL; the vertebral bodies; the intervertebral disks; and the ventral dura. The dorsal dura is sparsely innervated. In view of the relation with the sympathetic trunk (through the rami communicantes), these structures are also assumed to be sympathetically innervated. Sympathetic nerve fibers have indeed been recently identified in these networks.

Dura Mater
The dura mater is a strong connective tissue membrane surrounding the cerebral spinal fluid (CSF) space lined with the arachnoidea and sprouting side branches, which contain the anterior and posterior nerve roots, as well as the DRGs. These side branches constitute the dural sleeves or dural nerve root sleeves.

On a transverse section, the dural sleeves are located in the anterolateral quadrant of the spinal canal, at 10

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Figure 6. Transverse histological section at Level S2 and SI joint. Anterior is above in the figure. Mallory–Cason trichrome staining.

Figure 7. Histological cross-section at the level of intervertebral disk L4-5 (above) and L5-S1 (below) showing relationship between exiting nerve roots L4, L5, and S1, the dorsolateral intervertebral disk and the flaval ligaments plus facet joints; epid, epidural space. Mallory–Cason trichrome staining.
o’clock and 2 o’clock. (Figure 7a,b). The upper part is called the “shoulder,” while the lower part is called the “axilla,” corresponding to the shoulder and armpit parts of a jacket. The dural sleeve continues into the outer layer of the nerve, the epineurium. Within the intervertebral foramen, the dural sleeve is dorsally bounded by the ligamentum flavum, which is closely associated with the ventral capsules of the facet joints here (Figure 7).

MECHANISM OF RADICULAR PAIN

Radicular pain is not the result of nerve root compression.24–28,33,34 Compression causes nerve dysfunction (sensory and/or motor deficits),35 whereas pain requires an inflammatory reaction. This was demonstrated by a study of Howe36 where compression of a normal peripheral nerve only induced action potentials for a short duration, whereas compression of an inflamed peripheral nerve led to prolonged firing of the nerve. However, pressure itself can cause inflammation with infiltration of macrophages and inflammatory cytokines.37 Compression or fixation of the nerve root in the neuroforamen can lead to stretching, decreased intraneural microcirculation, and ischemia.18 Damage to endoneural blood vessels leads to breakdown of the blood-nerve barrier and intraneural edema, which further compromises the microcirculation of the nerve root. The long-standing intraneural edema leads to a vicious cycle with infiltration of fibroblasts, even more scar tissue formation, thus further compromising nerve root blood supply. Moreover, compression of nerve roots leads to a change of axonal flow and altered metabolism of neurotransmitters hereby impairing nerve function.37 Local demyelination sites will generate ectopic discharges and lead to altered sensations and/or spontaneous pain.31 The nucleus pulposus of the intervertebral disk itself contains a range of proinflammatory interleukines.25,29,34,38–40 A tear in the annulus fibrosis can cause large quantities of phospholipase A2 to be released into the epidural space, causing an inflammatory reaction further intensified by the release of TNF-α from mononuclear inflammatory cells.24–28,33,34

Spinal fibrosis is an important factor in nerve root compression and can be induced by spinal surgery itself. On the one hand, surgical repair can restore the nutritional status of the nerve (in terms of NGF supply), as it relieves the nerve root compression. However, it induces new tissue trauma, hemorrhage, and contamination with foreign materials, which may lead to renewed fibrosis formation. Epiduroscopy in patients with chronic radicular pain found fibrosis in nearly 100% of cases.21,22 MRI scans have also shown that high levels of fibrosis correlate with high pain levels.41

A logical therapeutic step would appear to be adhesiolysis with the aim of releasing the entrapped nerves, creating enough space around the nerve to restore both blood supply and the supply of nutrients to the nerve root from the CSF.

EVIDENCE

Until now, 1 prospective double-blind randomized controlled trial,42 9 prospective studies,21,22,43–49 and 3 retrospective studies50–52 yielded positive results after epiduroscopy in terms of pain scores and functional status. Most studies included patients with failed back surgery syndrome, 1 study included patients with degenerative lumbar spinal canal stenosis, and 1 study included patients with sciatica. One controlled randomized trial in patients with sciatica failed to show improvement when comparing epiduroscopy with caudal epidurals.53 Most of the reported epiduroscopy procedures used mechanical adhesiolysis by means of the epiduroscope or an endoscopic video-guided system followed by injection of a mixture of local anesthetic and steroids. A minority of the studies added clonidine or hyaluronidase. In one study, ozone and ciprofloxacin were injected.

In a prospective, randomized, double-blind study, Manchikanti et al.42 included patients with chronic radicular pain who lasted for a minimum of 6 months and failed to respond to other conservative treatment strategies, including X-ray-guided epidural injections and percutaneous adhesiolysis (“Racz procedure”). Group 1 functioned as a control group. In this group, the epiduroscope was introduced to the level of the sacral canal, and a mixture of a corticosteroid and a local anesthetic was administered. No attempt for adhesiolysis at the appropriate level was undertaken. Group 2 underwent epiduroscopy and suitable adhesiolysis in the target area, after which the same mixture of corticosteroid and local anesthetic was placed. The outcome parameters were pain, functional status, and psychological and behavioral status. Thirteen of the 23 patients in group 2 (57%) showed significant improvements in terms of pain scores after 1, 3, and 6 months. All other outcome measures, including psychometric tests, had also improved significantly after 1, 3, and 6 months. The control group showed improvement at
1 month and none thereafter. The authors concluded that epiduroscopy is an effective treatment, especially for patients who fail to respond sufficiently to epidural injections and percutaneous adhesiolysis.

Geurts et al.\textsuperscript{21} prospectively evaluated whether abnormalities identified on MRI scans could be confirmed with epiduroscopy and investigated whether targeted epidural injection of medication after adhesiolysis was able to reduce radicular pain. Epidural adhesions were found during the procedure in 19 of the 20 patients. In 8 of them, including 6 without a history of back surgery, these adhesions had not been observed on previous MRI scans. Six patients showed signs of nerve root inflammation. Eleven of the 20 patients showed a significant improvement in VAS scores after 3 and 12 months.

In a prospective study with 12 months follow-up by Richardson et al.,\textsuperscript{22,38} patients with chronic radicular pain showed significant improvement. Comparable outcomes were found in 2 retrospective evaluations by Manchikanti et al.\textsuperscript{30,51} based on 112 epiduroscopies in 85 patients with chronic radicular pain who had failed to respond to a conventional treatment including epidural corticosteroid injections. The epiduroscopy involved visualization of adhesions with subsequent adhesiolysis and the administration of a mixture of a corticosteroid and a local anesthetic. The results showed significant long-term effects and also confirmed the cost-effectiveness of the procedure.

Sakai et al.\textsuperscript{44} performed epidural adhesiolysis followed by injection of steroids and local anesthetics in 19 patients with chronic sciatica. Adhesiolysis was successful in 16 patients. Pain and disability scores significantly improved following epiduroscopy. Furthermore, sensory nerve function measured by current perception threshold improved equally.

Avellanal and Diaz-Reganon\textsuperscript{47} attempted an interlaminar approach for epiduroscopy. Although offering good pain relief (3 point VAS reduction) in 31.6% of patients at 6 months follow-up, the technique was hampered by 21% dural punctures.

Two research groups endeavored adhesiolysis techniques other than mechanical lysis with the epiduroscope. Raffaeli and Righetti\textsuperscript{38} used a Res-ablator with 4 Mhz radiofrequency output to break down adhesions in 14 patients. Fifty-seven percent of patients stated > 90% improvement after 1 month. Ruetten et al.\textsuperscript{45,46} used a Holmium:YAG laser in 2 prospective case series of 34 and 68 patients. Positive results (2 point VAS reduction) were obtained in 44% and 48.5% of patients, respectively, after 8 weeks. Although promising, these studies lack long-term follow-up and the results do not outmatch results of studies with “classic” mechanical adhesiolysis.

A recently published prospective, randomized study by Dashfield and colleagues appeared to yield unfavorable results.\textsuperscript{53} However, several concerns need to be addressed. First, none of the patients in this study had a history of surgery or failed back surgery syndrome with patients suffering from radicular pain for a maximum of only 18 months. Moreover, epiduroscopy in these patients revealed little scar tissue. Second, the researchers specifically mentioned that they did not flush the epidural space and adhesiolysis was only performed in 3 patients. In the control group, a mixture of corticosteroid and local anesthetic was administered caudally, while in the epiduroscopy group, the same mixture was injected in the epidural space near the affected nerve root. No significant differences were found between the 2 groups, with both groups showing a significant favorable short-term effect. The authors concluded that there was no added value of epiduroscopy in the administration of epidural corticoids. In a letter to the editor, Richardson et al.\textsuperscript{54} commented that flushing the epidural space and adhesiolysis are essential components of the procedure, and that the study by Dashfield et al. was therefore not comparable to any of the other studies of epiduroscopy published so far.

One study looked into the effect of epiduroscopy in patients with degenerative lumbar stenosis.\textsuperscript{43} Based on symptoms, the patients ($n = 58$, mean age 71 years) were divided into 2 groups according to the number of affected nerve roots: a monosegmental group ($n = 34$) and a multisegmental group ($n = 24$). All patients underwent epiduroscopy and were evaluated in terms of VAS scores for back and leg pain. During epiduroscopy, the epidural space was flushed, adhesiolysis was applied, and a mixture of a corticosteroid and a local anesthetic was placed. Relief of backache was found in both groups up to 12 months after the intervention. Only the monosegmental group reported significant improvement after 12 months, while the effect had waned after 3 months in the multisegmental group. Other than one accidental dural puncture, no complications were reported in this study. Apart from a biochemically based effect of adhesiolysis on radicular pain, it is conceivable, especially in this group of patients, that nerves need a certain amount of space to accommodate flexion and extension.\textsuperscript{55}
Five papers reviewed the literature concerning epiduroscopy, all yielding favorable conclusions.56–60

SIDE EFFECTS AND COMPLICATIONS

Reports of complications related to epiduroscopy are sparse and limited to the following case reports: retinal/vitreous hemorrhages61,62 related to rapid or large volume infusions in the epidural space; intravascular injections63; intrathecal injection of contrast dye leading to encephalopathy; rhabdomyolysis (irotolan);64 and postdural puncture headache.

The risk for radiation exposure during the epiduroscopy procedure was assessed in an in vitro model.65 While the calculated radiation dose for 1 epiduroscopy is below the threshold that could lead to organ injuries, care should be taken for accumulating exposure. Heavner and Bosscher,66 in a letter to the editor, offered tips to reduce the radiation exposure.

Contraindications

*Increased Intra-Abdominal Pressure.* Situations in which the intra-abdominal pressure is greatly increased, with a significant rise in the amount of venous blood in the plexus (eg, during pregnancy), could be regarded as a relative contra-indication for epiduroscopy, although Igarashi et al.23 have applied epiduroscopy in pregnant women.

*Duration of the Procedure and Increased Epidural Pressure.* The continuous inflow of saline may eventually lead to increased epidural pressure. If this results in a rise in the cerebrospinal fluid pressure to above arterial pressure, it affects the perfusion of the spinal cord and the nerve roots. Whether this necessitates continuous monitoring of the epidural pressure is still a subject of debate.

Increased epidural pressure can lead to an increased intracranial pressure around the anterior optic nerve, leading to macular hemorrhage and causing visual disturbances.62 This serious complication has, however, mostly been reported with epidural injections and generally resolves. The current hypothesis states that momentary sudden pressure increases in the cerebrospinal fluid can arise from excessively rapid injection of unduly large volumes in the epidural space. This implies that the inflow of saline during epiduroscopy should be carried out slowly and in small volumes, as indeed goes for epidural injections generally.

Other contraindications are as follows: local infection at the entry site; coagulopathy or use of anticoagulants; bladder or bowel sphincter dysfunction; obesity (BMI > 35); inability to lie in prone position > 60 min; inability to give informed consent; and allergy for contrast dye or local anesthetics.

**EVIDENCE GRADING**

A summary of the evidence grading is given in Table 4

<table>
<thead>
<tr>
<th>Technique</th>
<th>Assessment</th>
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<tr>
<td>Epiduroscopy with adhesiolysis and targeted therapy for FBSS</td>
<td>2 B+</td>
</tr>
<tr>
<td>Epiduroscopy without adhesiolysis and low back pain without history of surgery</td>
<td>2 B–</td>
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The use of epiduroscopy is recommended in patients with chronic lumbosacral radicular pain refractory to conservative or minimally invasive therapies. Surgical options must be exhausted or contraindicated and patients should have received optimal pharmacologic treatment. Epiduroscopy is best offered as part of a multidisciplinary approach with physiotherapy and/or psychological counseling as needed. Preferably, the procedure should be used in a research context in specialized centers.

**CLINICAL PATHWAY**

Correct performance of epiduroscopy requires special equipment and a trained multidisciplinary team. The clinical pathway described in Table 5 identifies the steps to be taken.

**PROCEDURE**

Epiduroscopy is performed after preprocedure antibiotic administration in sterile OR conditions under conscious sedation with continuous hemodynamic and respiratory monitoring. Generally, communication with the patient must be possible at all times during the intervention.

With the patient lying prone on the operating table, a pillow is placed underneath the abdomen to straighten the lumbar lordosis. The area around the sacral hiatus is disinfected and anesthetized with local anesthetic. After
a sterile drape has been placed over the patient, a Tuohy needle is inserted through the sacral hiatus under lateral X-ray control. Next, a guide wire is threaded through the Tuohy needle under fluoroscopic guidance. Using a Seldinger technique, an introducer is advanced over the guidewire into sacral epidural space to a level between S2 and S3, where a baseline epidurogram (Figure 8) may be made. Thereupon, the video-guided catheter containing the flexible epiduroscope is inserted. The video-guided catheter with epiduroscope is steered cranially under direct vision in the epidural space to the level of expected pathology in combination with fluoroscopy. To obtain a good visual field, the epidural space is irrigated and distended with saline. Pressure in the epidural space can be monitored. Although there is no support in the literature, it seems logical that the epidural pressure should not exceed the mean blood pressure. Once at the expected level of pathology, gently touching the nerve root with the video-guided catheter should reproduce the patient’s pain. Once adhesions are identified, attempts are made to rupture them mechan-
ically by gentle movements of the video-guided catheter and by bolus injections of small amounts of saline. In some patients, adhesions are so solid that adhesiolysis is impossible. In these patients and in the absence of inflammation, the procedure is strictly diagnostic. If there is inflammation visible, flushing the epidural space with saline and the medication is thought to play an important role. A postprocedure epidurogram (Figure 9) is made to record the result of the adhesiolysis. Finally, a mixture of local anesthetics and depot steroids (potentially also hyaluronidase and clonidine) is injected at the culprit level. Saline flushing must be suspended immediately if the patient complains of neck pain or headache. If these complaints disappear within 5 minutes, the procedure may be resumed; if they persist, the procedure must be discontinued. The procedure must also be discontinued in case the patient experiences severe paresthesias and/or pain. After the intervention, patients are monitored at the recovery room.

CONCLUSION
According to the available evidence, epiduroscopy is a safe treatment with no mortality and little morbidity. There is reasonable evidence for short and long-term effect in patients with chronic radicular pain due to failed back surgery syndrome. More controlled trials are needed to confirm the efficacy of this treatment and its long-term effects.

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